Abstract Title: Small Projects Rapid Integration and Test Environment (SPRITE): Application for Increasing Robustness

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Abstract: Marshall Space Flight Center's (MSFC) Small Projects Rapid Integration and Test Environment (SPRITE) is a Hardware-In-The-Loop (HWIL) facility that provides rapid development, integration, and testing capabilities for small projects (CubeSats, payloads, spacecraft, and launch vehicles). This facility environment focuses on efficient processes and modular design to support rapid prototyping, integration, testing and verification of small projects at an affordable cost, especially compared to larger type HWIL facilities.

SPRITE (Figure 1) consists of a "core" capability or "plant" simulation platform utilizing a graphical programming environment capable of being rapidly re-configured for any potential test article's space environments, as well as a standard set of interfaces (i.e. Mil-Std 1553, Serial, Analog, Digital, etc.). SPRITE also allows this level of interface testing of components and subsystems very early in a program, thereby reducing program risk.

Figure 1: SPRITE Functional Overview

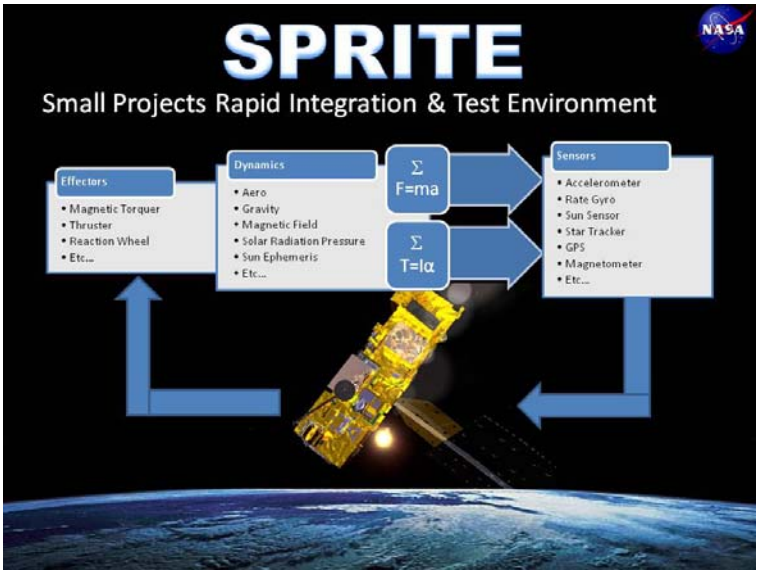
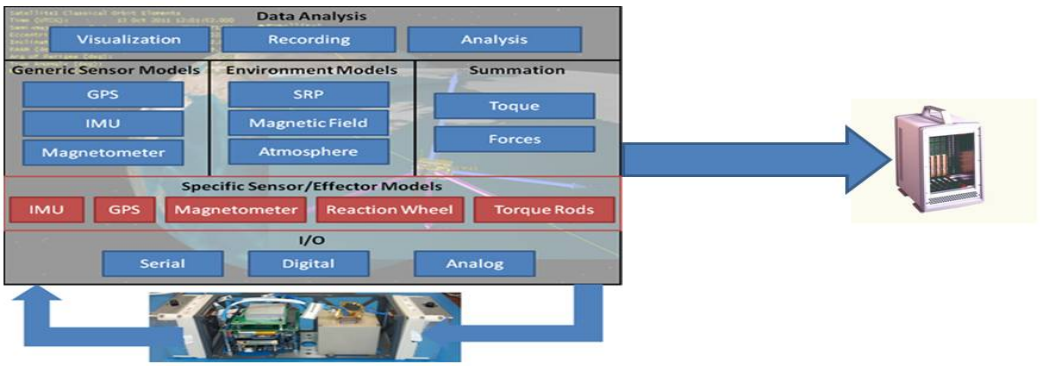


Figure 2: SPRITE Components



The SPRITE laboratory is leveraged off of MSFC's System Integration Laboratory (SIL) developed for the Ares I and Space Launch System (SLS) programs. The SIL enables real-time simulation of a human-rated launch vehicle's ascent flight with flight-like avionics and software. SPRITE adapts the SIL's simulation framework and modular design for applications on a smaller scale than the complex launch vehicles, and adapted the architecture to support rapid turn-around in all aspects of the life cycle. This approach provides the end-user/customer a simple, affordable method to minimize project risk, schedule, and budget, while maintaining high confidence of mission success and satisfying flight readiness requirements.

MSFC is now making this capability portable by containing all the simulation computers and interfaces in a single chassis the size of a medium-sized suitcase. This enables MSFC to bring the V&V environment to the customer so that the flight article doesn't have to undergo the risky transportation process or leave its clean-room environment. As interest is growing in small, responsive launchers, SPRITE provides the capability and portability to exercise the ascent vehicle's avionics through a simulated trajectory, exactly like SIL did for Ares I and performs for SLS.

SPRITE also serves as a development environment or "innovation space" for rapid development of innovative concepts and provides an avenue for actual development and test of these new technology developments. SPRITE also enables quick evaluations of COTS components for applicability to space flight applications. SPRITE has already facilitated testing of custom components and new technologies, emphasizing that the existence of this laboratory has already been used for several proof-of-concept proposals, and is included in current proposals. SPRITE has also been the conduit for innovative exchanges between MSFC and universities and cross-discipline technical exchanges by MSFC engineers.

Potential SPRITE Applications

<u>Closed Loop Testing</u>

For small spacecraft, such as CubeSats, the flight computer processors can be connected to the SPRITE real-time simulation computer, either directly or via development board interface. Simulated sensor measurements can then be fed into the flight processor. This allows the flight processor to exercise the flight software, operating on these simulated sensor inputs. The flight software and processor then output actuator commands back to the real-time simulation computer. The actuator commands are applied to the simulated vehicle dynamics, fed into the sensor models, and the loop starts over again. In another scenario, actual flight sensors and actuators can be included in the loop to exercise the actual hardware interfaces of those components. MSFC has succeeded in bringing this HWIL capability, previously reserved for V&V of large systems, into the realm of small systems.

Operational Check-Out

SPRITE can also provide an essential service to spacecraft once they achieve operations on orbit. If anomalies occur during the mission, SPRITE has the ability to replay telemetry through the flight system within the real-time simulation. This greatly aids in troubleshooting on-orbit problems. Once the problems have been identified and solutions developed, SPRITE is again there to verify the software fixes before uploading them to the spacecraft.

Flight Software Development

SPRITE is conducive to a model-based approach to software development. One can develop flight code, and, with the assistance of the development board, test the prototype flight code in the real-time simulation. This way, early versions of flight software can be tested, and complex interfaces can be checked, early in the development cycle.

Power Management

As power management can be an issue on small CubeSats, SPRITE can help verify performance of the power system. All subsystems can be integrated together in the SPRITE lab and the simulation run while engineers monitor power draw across all subsystems. Power draw can be assessed at different points throughout the mission timeline in the real-time simulation environment as different subsystems demand varying power levels depending on what the spacecraft is required to do.

Guidance Navigation and Control

Navigation and attitude determination systems can be evaluated by flowing simulated data into navigation and attitude determination filters. Inexpensive IMUs can be evaluated with the filters, and interfaces quickly resolved.

Telemetry System Verification

SPRITE can support telemetry system testing. Telemetry archived on the CubeSat can be transmitted, via the CubeSat's own RF transmitter, to a separate receiver located in the SPRITE lab. That way, end-to-end telemetry can be checked out versus the mission timeline inside the simulation.

The SPRITE has become an integral tool for rapid development, design, test, and verification; provides the capability to support small project location needs; and supports the engineers in assessing innovative concepts, including COTS, custom hardware/software concepts, and lifecycle. SPRITE will continue to evolve as concepts are proven and technical interchanges occur and lessons learned are incorporated. This will result in better processes, more robustness and capability as SPRITE continues to mature.